MATH 2241: Mathematical Modeling of Biological Systems

Course Description and Syllabus

Instructors: Duane Nykamp (Mathematics), Allison Shaw (Ecology, Evolution, Behavior)

Prerequisites: Math 1241 or 1271 or 1371 or equivalent

Credits: 3

Catalog description: Development, analysis and simulation of models for the dynamics of biological systems. Mathematical topics include discrete and continuous dynamical systems, linear algebra, and probability. Models from fields such as ecology, epidemiology, physiology, genetics, neuroscience, and biochemistry.

COURSE OVERVIEW

This course provides an introduction for developing, analyzing, and interpreting mathematical models of biological systems. We will cover a variety of different mathematical approaches and draw on examples from biological systems. Throughout this course, our general goal is to use mathematics as a tool for gaining a deeper understanding of biological systems and their dynamics.

The specific learning goals of this course are:

1. Introduce the connections between biological questions and mathematical concepts.
2. Develop the mathematics of dynamical systems, linear algebra, and probability through modeling biological systems.
3. Explore the utility of using mathematical tools to understand the properties and behavior of biological systems.
4. Develop facility in interpreting mathematical models and the conclusions based on the models.

CLASS FORMAT

To help students achieve these learning goals, Math 2241 will use an active learning format for class instruction. The lecture material will be posted online in the form of videos and text that will be watched and read at home. In class time will be spent working through problems and projects in groups.

COURSE TOPICS

1. *Class-structured models* *3 weeks*
   - multi-dimensional linear discrete dynamical systems
   - matrix equations and eigenvalues of matrices
   - age-structured models for population dynamics
   - biological examples: sea turtle conservation, gut microbiome
2. *Two-dimensional continuous dynamical systems* *3 weeks*

equilibria and nullclines
phase plane analysis
stability of equilibria
partial derivatives
biological examples: infectious disease and vaccination, interspecific competition, neuron spike generation, predator-prey

3. *Probabilistic modeling* *3 weeks*
   probability distributions, independence, conditional probability, random variables
   probabilistic inference
   biological examples: population growth, genetics, disease testing, cancer
4. *Spatial modeling* *3 weeks*
   two-patch models with dispersal
   metapopulation models, occupancy
   random walks and the diffusion equation
   interpretation of partial differential equations
   biological examples: habitat loss, molecular diffusion, macrophage movement
5. *Modeling philosophy* *2 weeks*
   development of a mathematical model
   appropriate use and limitations of mathematical models

COURSE MATERIALS

Math Insight
Lecture videos, additional expository material, interactive applets, quizzes, and exercises will be posted on the Math Insight website.

ASSESSMENT

The course grade will be based on points achieved. The points will be distributed approximately as follows:

course component	points each	total points
problem sets (best 30 scores out of 32)	3	90 (6%)
projects (best 9 scores out of 10)	30	270 (18%)
quizzes (best 10 scores out of 12)	8	80 (5%)
exams (4 total)	200	800 (52%)
final	300	300 (19%)
TOTAL		*1540 (100%)*

Gateway exam

In order to pass the course, a passing grade must be achieved on the calculus “gateway” exam on algebra, simple derivatives, and integrals.

The gateway exam can be taken multiple times until a passing grade is achieved. To maintain good standing in the course, minimum scores must be achieved by the following deadlines:

A score of 60% or above by the end of the 1st week of the semester
A score of 80% or above by the end of the 4th week of the semester

Students who fail to reach the required score on the gateway exam can either withdraw from the course by the drop deadline or receive a failing grade.

Exams

The course is divided into five modules. The first four have an associated exam. Each exam will be offered twice. If you take the exam twice, your score for the exam will be the maximum score of the two attempts.

The last module will not have a separate exam, but the exam for the last module will be combined with the comprehensive final exam. The final exam will be XX time on XX date. The final exam cannot be retaken.

Quizzes

Quizzes will be taken online. Each quiz can be taken repeatedly up to the deadline.

Problem sets

Problem sets will be worked on in groups during class. Portions of each problem set will entered online for grading. Some problem sets may contain a hand graded portion, in which case, each student should hand in their work individually.

Projects

Students will complete the following ten synthesis projects (two per module) where they apply math skills to different biological scenarios on a written worksheet. Students will work in groups of three and submit one final worksheet per group.

1. *Class-structured models*
   1.1. Sea turtle conservation
   1.2. Gut microbiome
2. *Two-dimensional continuous dynamical systems*
   2.1. Infectious diseases and vaccination
   2.2. Interspecific competition
3. *Probabilistic modeling*
   3.1. Neuronal decoding
   3.2. Cancer development
4. *Spatial modeling*

4.1. Habitat loss
4.2. Molecular diffusion in a cell
5. *Modeling philosophy*
5.1. Create-your-own-model
5.2. Synthesis

POLICIES

Make-ups
Students must make arrangements in advance if they will not be handing in homework on time or will miss an exam. Exam absences due to recognized University related activities, religious holidays, verifiable illness, and family/medical emergencies will be dealt with on an individual basis. See official University Policy on Makeup Examinations for Legitimate Absences, http://www.policy.umn.edu/Policies/Education/Education/MAKEUPWORK.html.

Scholastic conduct
We expect the highest standards of conduct from members of this class. Cases of academic dishonesty will be treated with utmost seriousness. See Student Conduct Code, http://regents.umn.edu/sites/regents.umn.edu/files/policies/Student_Conduct_Code.pdf.

Student privacy and course website
In this class, our use of technology will sometimes make students' names and U of M Internet IDs visible within the course website, but only to other students in the same class. Since we are using a secure, password-protected course website, this will not increase the risk of identity theft or spamming for anyone in the class. If you have concerns about the visibility of your Internet ID, please contact your instructor for further information.

Incompletes
A final grade of incomplete is given only if you have successfully completed all but a small portion of the work of the course, and have a very compelling, well documented excuse from completing the course. Simply being behind in your work does not qualify you for an incomplete.

Drop dates
You may drop the course without permission by the end of the eighth week of the semester. If you drop before the end of the second week, no mention of the course will appear on your transcript. Otherwise, you receive a "W" for the course.

Equity and Equal Opportunity
The University provides equal access to and opportunity in its programs and facilities, without regard to race, color, creed, religion, national origin, gender, age, marital status, disability, public assistance status, veteran status, sexual orientation, gender identity, or gender expression. For more information, see the Board of Regents Policy, http://regents.umn.edu/sites/default/files/policies/Equity_Diversity_EO_AA.pdf.

Accessability
The University of Minnesota is committed to providing equitable access to learning opportunities for all students. The Disability Resource Center (DRC) is the campus office that collaborates with students who have disabilities to provide and/or arrange reasonable accommodations. If you have, or think you may have, a disability (e.g., mental health, attentional, learning, chronic health, sensory, or physical), please contact the DRC at 612-626-1333 to arrange a confidential discussion regarding equitable access and reasonable accommodations. If you are registered with the DRC and have a current letter requesting reasonable accommodations, please contact your instructor as early in the semester as possible to discuss how the accommodations will be applied in the course. For more information, please see the DRC website, https://diversity.umn.edu/disability/.

Mental Health and Stress Management
As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance and may reduce your ability to participate in daily activities. University of Minnesota services are available to assist you. You can learn more about the broad range of confidential mental health services available on campus via the Student Mental Health Website: http://www.mentalhealth.umn.edu.

Sexual Harassment
Sexual harassment interferes with academic performance and creates a hostile academic environment. Such behavior is not acceptable in the University setting. For additional information, see the Board of Regents Policy, http://regents.umn.edu/sites/default/files/policies/SexHarassment.pdf.